PHYS-3301

Lecture 20

Nov. 5, 2024

Presentations

3201-501 (11/19)
Akin, Baker, Birdi, Cole, Delashaw, Ellerbrook, Garcia, Land, Matt, McKinley, O'Donnell, Sory, Torres-Rodriguez, Vasquez, Yoon
Group A (5): Birdi, Cole, Ellerbrook, O'Donnell, Yoon
Group B (5): Land, McKinley, Sory, Torres-Rodriguez, Vasquez
Group C (5): Baker, Delashaw, Garcia, Matt

3201-502 (11/26)
Aravind, Calvert, Campbell, Clapshaw, DeBreau, Higgins, Rucker, Saldivar, Simon
Group A (3): Calvert, DeBreau, Saldivar
Group B (3): Aravind, Bell, Gist, Simon
Group C (3): Clapshaw, Higgins, Rucker

Please send me the title of your presentation (20 min) by 11/14

e.g., Previous Presentations

Nov 28	Group	Speakers	Title
08:05 – 08:25	3201-501 Group A	Roper, Holder, Klarich	Black Holes
08:25 – 08:50	3201-501 Group B	Ormond, Veraa	Quantum Optics
08:55 – 09:15	3201-501 Group C	Schroeder, Casadei	Using Electronic density and functionals to describe multi-atom systems Part 1: Particle in a box and the wave function. Part 2: Methods on how multi atom systems are solved.
09:15 – 09:25		Martinez	Quantum Dots
Nov 30	**Group**	**Speakers**	**Title**
08:05 – 08:25	3201-502 Group A	Mcclure, Alvord, Catano	Quantum Entanglement
08:25 – 08:50	3201-502 Group B	Rana, Gist, Bell	Radiation and Radioactive Decay
08:50 – 09:15	3201-503 Group C	Stines, Lopez, Valle	Quantum Computing
09:15 – 09:25		Lascano	Photovoltaic Effect

Nov 29	Group	Speakers	Title
08:05 – 08:23	501 Group A	Singh, Prather, Sides	Wave Function Realism vs. Wave Function Instrumentalism
08:24 – 08:42	501 Group B	Hanes, Solis, Prime	The Role of Quantum Entanglement in Neuroscience
08:43 – 09:01	501 Group C	Holder, Roessler, Smith	History of the Quark
09:02 – 09:20	502 Group A	Kahrhoff, Silva, Torres, Martinez	Gravitational Waves and Gravitons
Dec 1	**Group**	**Speakers**	**Title**
08:05 – 08:23	502 Group B	Solodukhina, Walker, Margeta-Cacace	Data Compression of Permutations for Quantum Bits
08:24 – 08:42	502 Group C	Mahmoud, Geronimo, Musella	
08:43 – 09:01	503 Group A	Droemer, Mailman	The Zeeman Effect and how it Relates to Astrophysics
09:02 – 09:20	503 Group B	Lascano, Newman, Patton	The Effect of Quantum Tunneling on Semiconductor Technology.

Chapter. 8
Spin & Atomic Physics

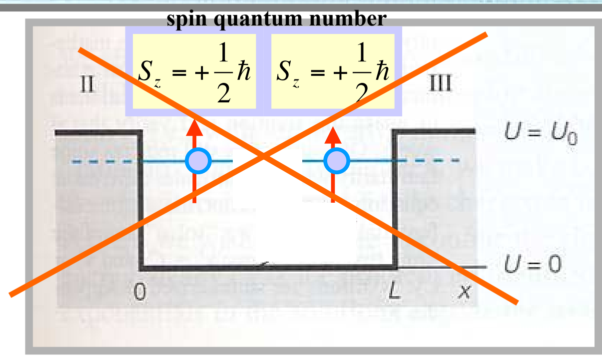
Outline:

- Evidence of Angular Momentum Quantization
- Identical Particles
- The Exclusion Principle
- Multi-electron Atoms & the Periodic Table
- Characteristic X-Rays

It's open said that in Q.M. there're only 3 bound-state problems solvable (w/o numerical approximation tech.)
1. Infinite well, 2. Harmonic oscillation, 3. hydrogen atom – all 1-particle problem.
Most real application: multiple system. so, let's start an atom with multiple electrons

The *Pauli Exclusion Principle* for Fermions

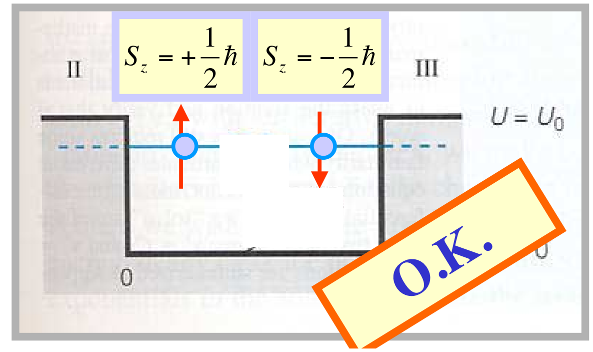
No two indistinguishable fermions may occupy the same individual-particle state.



$$S_z = \pm\frac{1}{2}\hbar$$

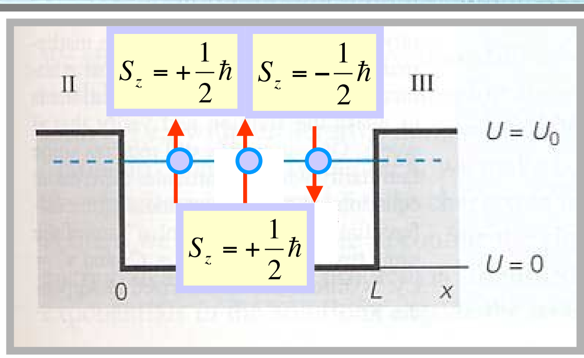
The *Exclusion Principle* for Fermions

No two indistinguishable fermions may occupy the same individual-particle state.



The *Exclusion Principle* for Fermions

No two indistinguishable fermions may occupy the same individual-particle state.



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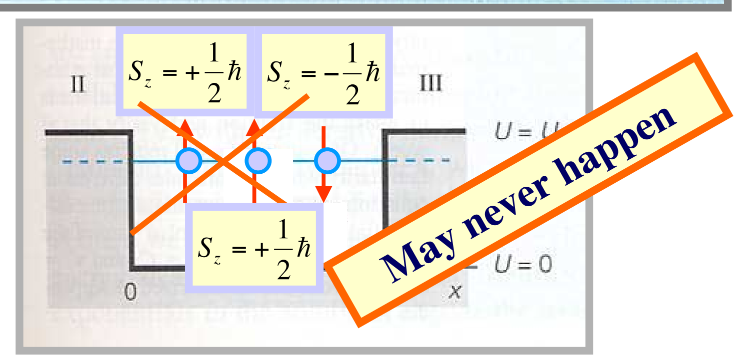
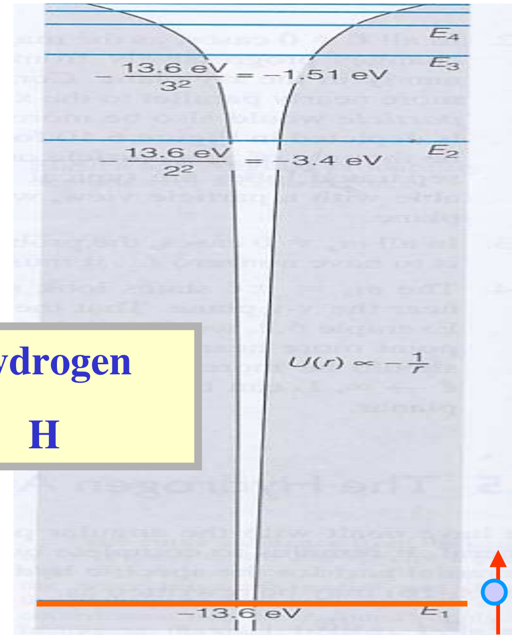
No two indistinguishable fermions may occupy the same individual-particle state.



Let's "create" multi-electron atoms

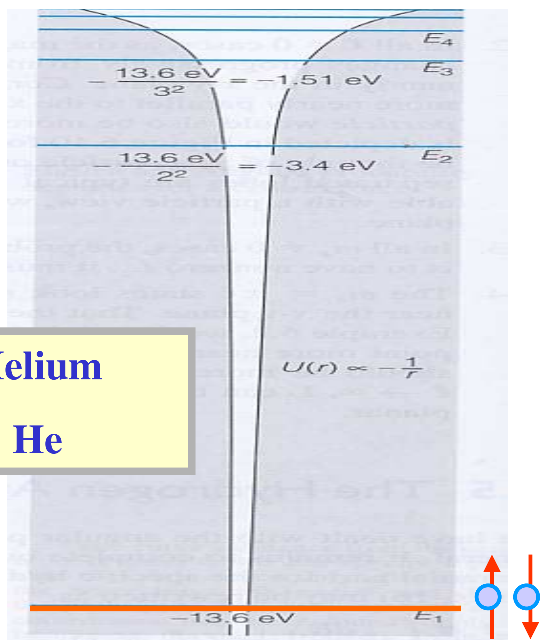
Our Toolkit:

- The Schrodinger Equation
- The Exclusion Principle
- Quantization of Energy Levels
- "Progressive Occupation" of Energy Levels



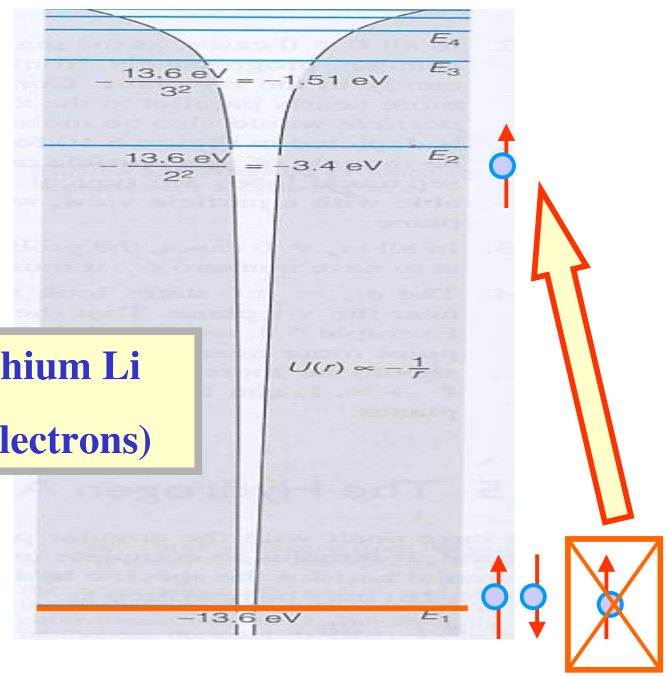
Hydrogen

H



Helium

He



Lithium Li

(3 electrons)

Energy Levels

Energy

n	1	2				3									…	n
ℓ	0	0	1			0	1			2					…	$0, \ldots, n-1$
m_ℓ	0	0	−1	0	+1	0	−1	0	+1	−2	−1	0	+1	+2	…	$-\ell, \ldots, +\ell$
Degeneracy	1	4				9									…	n^2

Hydrogen

H, ground state

Energy Levels

Energy

n	1	2				3									…	n
ℓ	0	0	1			0	1			2					…	$0, \ldots, n-1$
m_ℓ	0	0	−1	0	+1	0	−1	0	+1	−2	−1	0	+1	+2	…	$-\ell, \ldots, +\ell$
Degeneracy	1	4				9									…	n^2

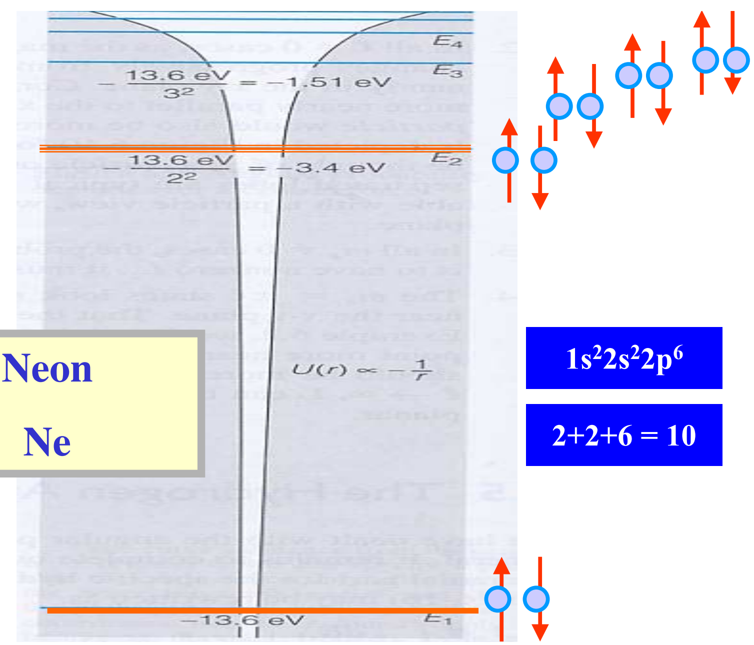
He 2-electrons

Energy Levels

Energy

n	1	2				3									…	n
ℓ	0	0	1			0	1			2					…	$0, \ldots, n-1$
m_ℓ	0	0	−1	0	+1	0	−1	0	+1	−2	−1	0	+1	+2	…	$-\ell, \ldots, +\ell$
Degeneracy	1	4				9									…	n^2

Neon (Ne) 10-electrons



Neon

Ne

$1s^2 2s^2 2p^6$

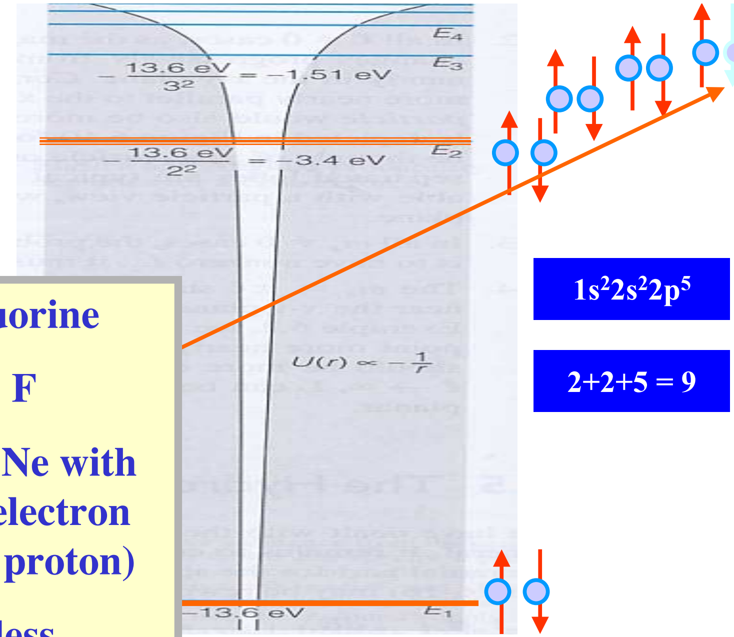
2+2+6 = 10

Energy Levels

Energy																
n	1	2				3									…	n
ℓ	0	0	1			0	1			2					…	$0, \ldots, n-1$
m_ℓ	0	0	−1	0	+1	0	−1	0	+1	−2	−1	0	+1	+2	…	$-\ell, \ldots, +\ell$
Degeneracy	1	4				9									…	n^2

Fluorine: 9-electrons

$1s^2 2s^2 2p^5$



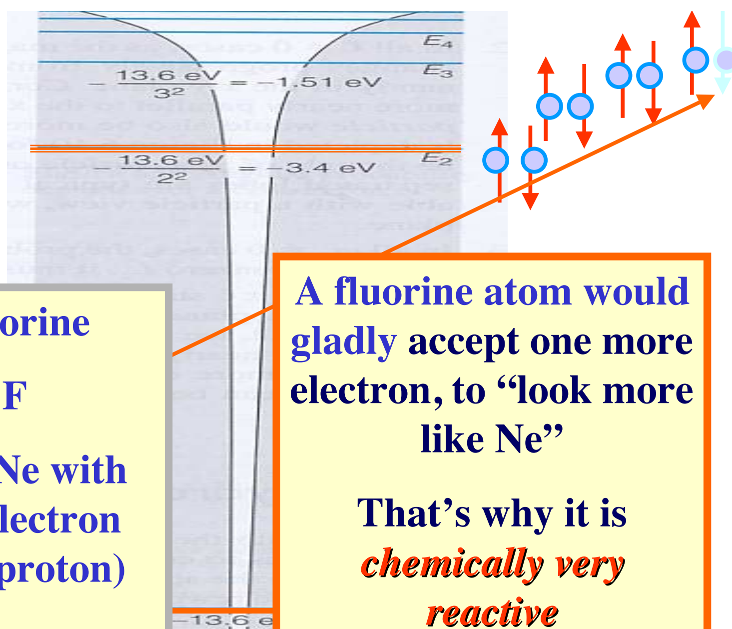
Fluorine

F

Like Ne with one electron (and proton) less

$1s^2 2s^2 2p^5$

2+2+5 = 9



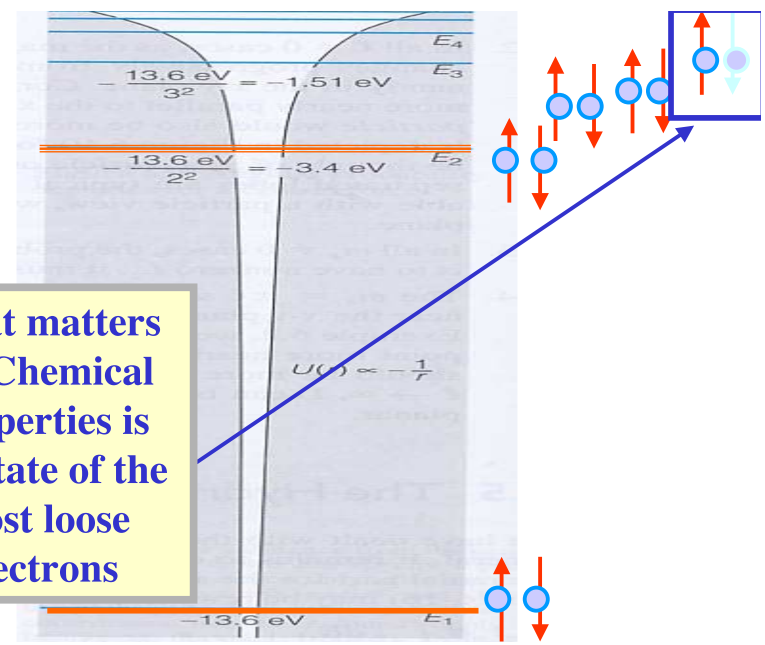
Fluorine

F

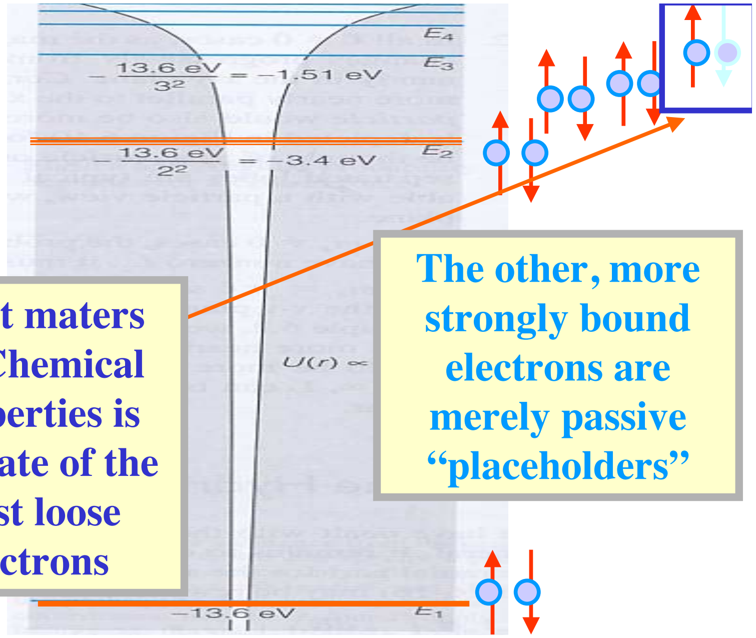
Like Ne with one electron (and proton) less

A fluorine atom would gladly accept one more electron, to "look more like Ne"

That's why it is *chemically very reactive*



What matters for Chemical Properties is the state of the most loose electrons



What maters for Chemical Properties is the state of the most loose electrons

The other, more strongly bound electrons are merely passive "placeholders"

The traditional naming scheme

Letter	s	p	d	f	g	h
Value of ℓ	0	1	2	3	4	5

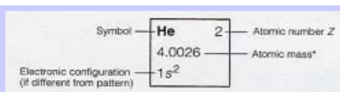
Principal quantum number "n"

F: $1s^2 2s^2 2p^5$

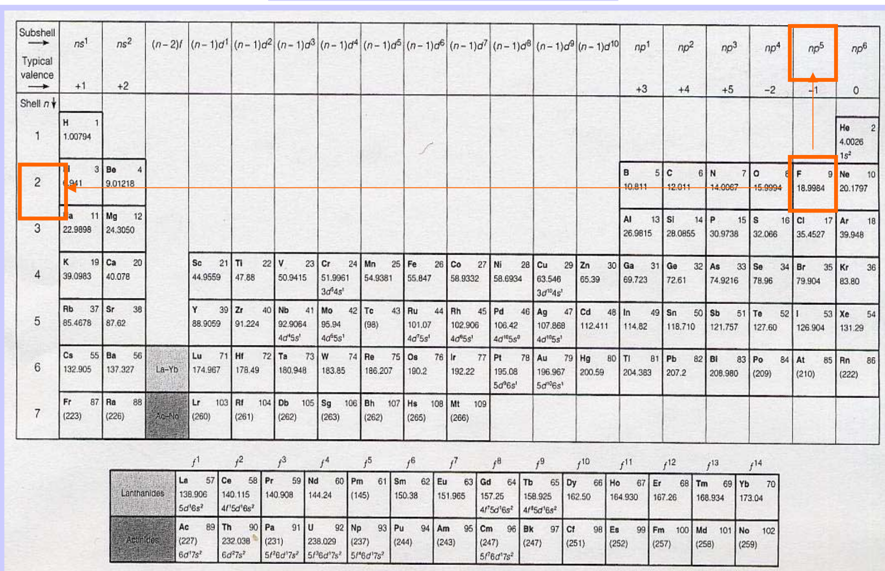
Ne: $1s^2 2s^2 2p^6$

Na: $1s^2 2s^2 2p^6 3s^1$

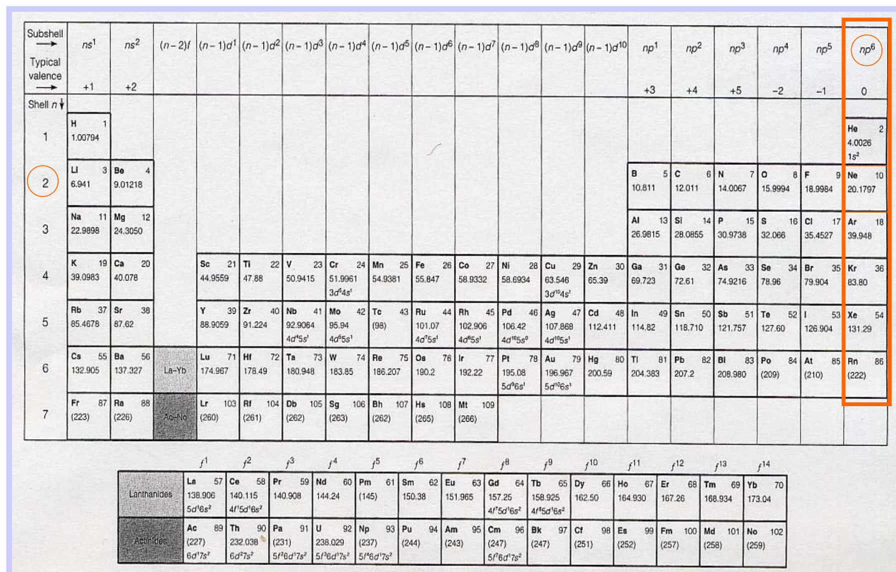
The number of electrons in that "subshell"



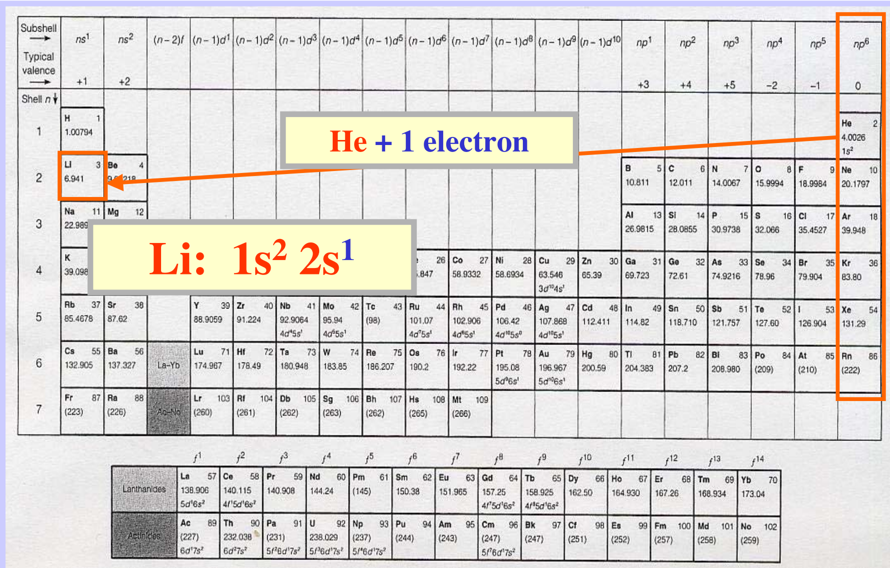
$1s^2 2s^2 2p^5$

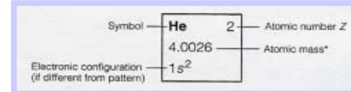


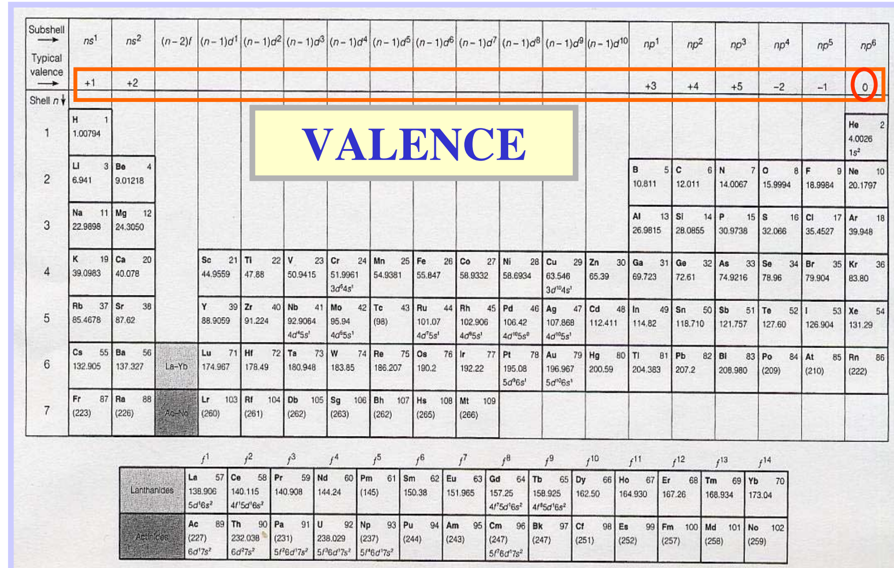
Noble gasses



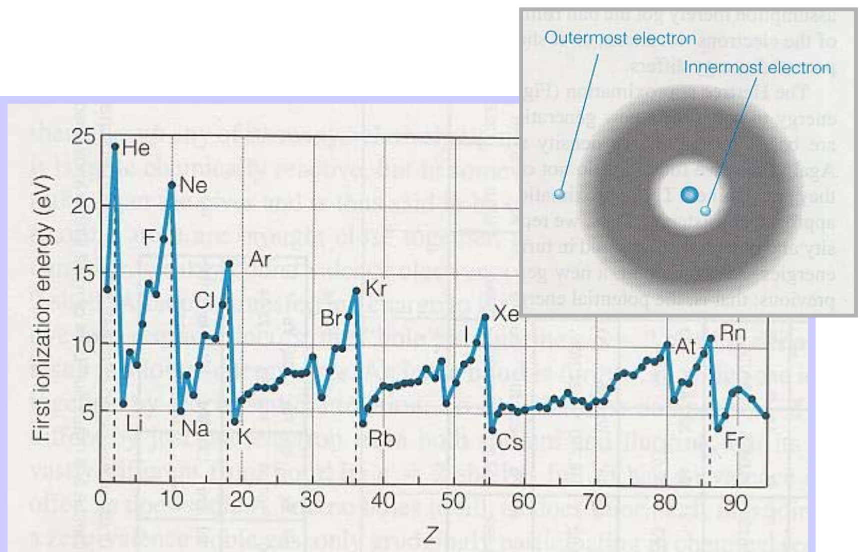
Noble gasses

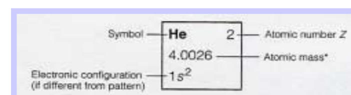


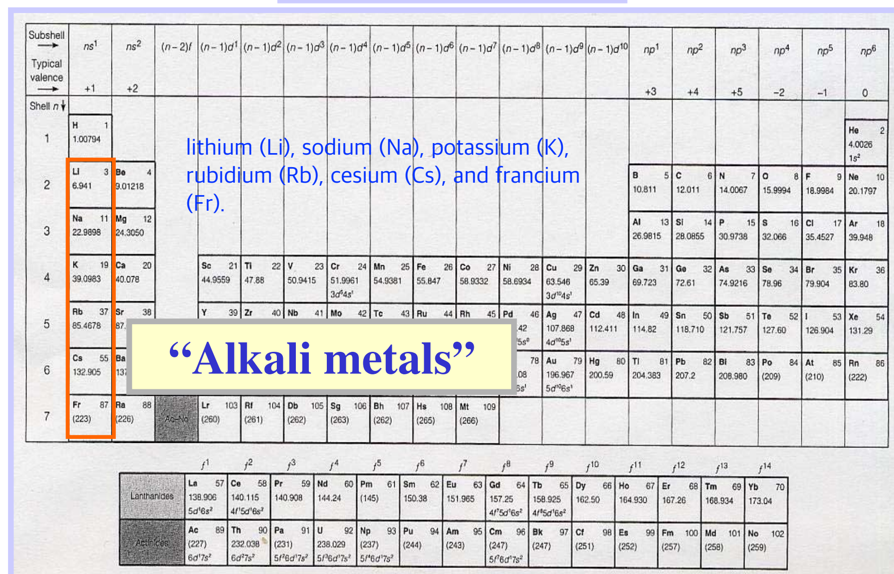




First Ionization Energy







Chapter. 9
Statistical Mechanics

Statistical mechanics is NOT non-classical or modern physics in the same sense that special relativity and QM are. Rather, it's a distinct area of physics that applies to many others; either classical or QM.

Q:: Why study it now? A:: many modern physics require it.
e.g. A gas laser: thermodynamics system of gas molecules
A semiconductor: thermodynamics system of atom bound in a solid lattice

**** Thermodynamic system = countless particles; precise average behavior.**

Chapter. 9
Statistical Mechanics

Outline:

- Historical Overview
- The Boltzmann Distribution
- Maxwell Velocity Distribution
- Equipartition Theorem
- Maxwell Speed Distribution
- Classical and Quantum Statistics
- Fermi-Dirac Statistics
- Bose-Einstein Statistics

9.1: Historical Overview

Statistics and probability
- New mathematical methods developed to understand the Newtonian physics through the 18th and 19th centuries.

Lagrange around 1790 and **Hamilton** around 1840.
- They added significantly to the computational power of Newtonian mechanics.

Pierre-Simon de Laplace (1749-1827)
- Made major contributions to the theory of probability

Historical Overview

Benjamin Thompson (Count Rumford)
- Put forward the idea of heat as merely the motion of individual particles in a substance

James Prescott Joule
- Demonstrated the mechanical equivalent of heat

James Clark Maxwell
- Brought the mathematical theories of probability and statistics to bear on the physical thermodynamics problems
- Showed that distributions of an ideal gas can be used to derive the observed macroscopic phenomena
- His electromagnetic theory succeeded to the statistical view of thermodynamics

Historical Overview

Einstein

- Published a theory of Brownian motion, a theory that supported the view that atoms are real

Bohr

- Developed atomic and quantum theory